INVESTIGATION OF THE SUITABILITY OF PERIWINKLE SNAIL SHELLS AS CARBURIZING MATERIAL FOR THE SURFACE HARDNESS IMPROVEMENT OF LOW CARBON STEEL

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ABSTRACT: *The carburization potential of periwinkle snail shells as a carburizing material for the surface hardness improvement of low carbon steel have been studied using the pack carburizing process. The carburizing process was carried out at the temperatures of 850 to 950^{0}C at the soaking time interval of 30, 45 and 60minutes. The carburized steel specimens were quenched in water and then tempered at 200^{0}C for half an hour to relieve the residual stresses introduced as a result of quenching. Standard methods were adopted to determined the surface hardness and impact notched strength of the carburized and uncarburized test specimens. Micro-examination was also performed using standard metallographic techniques to observe the influence of the absorbed carbon on the microstructure of the carburized steel specimens. The results of the experiment clearly showed that the carburizing material greatly enriched the steel surface with carbon as exhibited by the surface hardness values. It was observed that the process variables (carburizing temperatures and soaking time) had significant effect on the surface hardness and impact notched strength of the carburized steel specimens. The surface hardness of the carburized steel progressively increases while the impact notched strength remarkebly decreases with increase in carburizing temperature and soaking time. The peak surface hardness values of 53.7, 58.4 and 59.1 HRC were obtained at the caburizing temperature of 950^{0}C for the soaking time of 30, 45 and 60minutes respectively. The uncarburized steel had the highest impact notched strength of 27J while the minimun impact notched strength of 9J was obtained for the specimen carburized at 950^{0}C for 60minutes soaking time.*

KEYWORDS: Surface Hardness, Impact Strength, Low Carbon Steel, Periwinkle Shell

INTRODUCTION

Carburizing is a thermochemical diffusion process in which the steel will pick up carbon to a quantity determined by the carbon potential of the furnace atmosphere, heating temperature, holding time and the carbon activity between the furnace atmosphere and the material. The process allows the enrichment of the surface carbon of low carbon steel with carbon, inorder to develop a combination of high hardness as well as high toughness and impact strength of low carbon steel core as required by numerous engineering parts in service life such as gears, ball bearings, shafts, rock-drill bits, etc. (Smith, *et al.*, 2008 and Khanna, 2008). The process is one of the most widely used surface hardening method for obtaining unique balanced of properties in steels for many years. Steels with low carbon content are characterized by good

Print ISSN: 2055-8112: Online ISSN: 2055-8120

toughness and ductility, but low strength and wear resistance. By locally increasing the carbon content at the surface, followed by appropriate heat treatment, a hardened case surface with good wear resistance, fatigue strength and a tough, ductile core to inhibit the growth of any cracks that might form at the surface will be obtained. Such a steel will be tougher than a through-hardened medium carbon steel with the same surface hardness (George and Gabriel, 2009).

The process of carburizing involves diffusing carbon into a low carbon steel alloy to form a high carbon steel at temperatures generally between 850 and 950^{o}C, at which austenite, with its high solubility for carbon is the single stable phase (Singh, 2011). Hardening is accomplished when the high carbon surface layer is quenched to form martensite, so that a high carbon martensitic case with good wear resistance is superimposed on a tough low carbon steel core. Carburizing steels for case hardening usually have base-carbon contents of about 0.2%, with the carbon content of the carburized layer generally being controlled at 0.8 and 1%C. However, surface carbon is often limited to 0.9% because too high a carbon content can result in retained austenite and brittle martensite. According to Singh (2011), the use of very high carburizing temperatures decrease drastically the service life of the furnace parts like electrical resistors, etc., and also have an adverse effects on the structure of the steel as the grains of the case as well as the core may get coarsened.

Available researches has shown that extensive work have been carried out on different organic and inorgnic materials to establish their suitability as carburizing medium for the surface hardening of low carbon steel but it is realized that there are other materials especially of marine origin whose potential have not been adequately exploited. This probably could have accounted for the recent research interest by many researchers.

Nwoke, *et al*. (2014), Studied the effect of process variables on the mechanical properties of surface hardened mild steel quenched in different media and concluded that increased treatment temperature and soaking time greatly improved the surface hardness while the impact strength and ductility decreases. Ihom, *et al*.(2012), investigated the possibility of using *arecaceae* flower droppings for surface hardness improvement of mild steel. The process was carried out at a temperature of 920^{o}C for 3hours and the results showed that *arecaceae* flower droppings is a suitable waste material for improved surface hardness as it imparted a maximum hardness value of 56HRC and effective case depth of 0.7mm to the mild steel. Kumar and Gupta, (1995) and Kumar, (1994), carried out extensive studies on low stress abrasive wear characteristics of carburized mild steels, and heat tested medium carbon and alloy steels. The authors found out that the hardness and abrasion resistance of carburized mild steels increased considerably with increase of carburization temperature and soaking time; use of coal-tar pitch and quenching oil on mild steel surface and its subsequent carburization in charcoal greatly improved the wear resistance of carburized mild steel; the highest abrasion resistance was observed in the steel samples carburized in partially burnt charcoal and the hardness and wear resistance values of mild steels carburized by using coal tar pitch were comparable with those of heat treated high carbon low Cr steels.

The focus of this research work is to investigate the suitability of Periwinkle-snail Shells as an economical and viable alternative source of carburizng material that could be used for the surface hardening of low carbon steel for improved wear resistance and good fatigue strength for use in service life applications where these properties are the most essential and expected of the steel, especially in many rotating or sliding parts. The base approach consist of

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correlation of the microstructures obtained with the mechanical properties, measure of the surface hardness of the carburized steel to establish the carburizing success and studying the impact properties to evaluate the embrittlement, caused by the surface treatment.

Festus *et al*., (2012) reported that Periwinkle Shell is a waste product generated from the consumption of a small greenish-blue marine snail (Periwinkle), housed in a V shaped spiral shell, found in many coastal communities within Nigeria and World wide. The Shells are very strong, hard and brittle. In Nigeria, Periwinkles are found mostly in the Niger Delta areas in the South-South and Badagry in the South-West zones. The peoples of this areas consume the edible part as sea food and disposed off the Shells as waste materials. This waste materials are utilized by few as coarse aggregate in concrete for the paving of water logged areas while large quantity of the Shells are unutilize and disposed off thereby creating environmental concern. It is in view of this that the authors attempt to study the suitabilty of this wastefull material for the carburizing of low carbon steel for engineering applications, thereby promoting better use of limited resources and make the environment free of disposed Periwinkle snail Shells.

Materials and Equipment

The materials and equipment utilized for the study were; low carbon steel, periwinkle snail shells, BS sieve(75 microns), steel boxes, barium carbonate, electric furnace, weighing balance, dynamic hardness tester (Rockwell scale C), charpy impact testing machine, fireclay and tong.

Experimental Procedures

The commercial grade of the low carbon steel used in the study was sourced from the central store of the National Metallurgical Training Institute, Onitsha. The chemical composition of the low carbon steel as-received is shown in Table 1. The periwinkle snail shells (Figure 1) were sourced from Ogbaru market, Onitsha, Anambra State, Nigeria. They were cleaned and calcined in an electric furnace at 500^{o}C to carbonized them and thereafter grinded and sieved througth BS sieve (75 microns) to fine ash. A total of 18 test specimens prepared according to the specification of each test (hardness and charpy impact) as per ASTM standard were packed in heat resistant metal boxes (100x80x65mm) sizes, embedded in them a powdery mixture of 85% carbonized periwinkle shells and15% of barium carbonate ($BaCO_3$). The boxes were sealed with fireclay made into a paste with water and allowed to dry on the surface before placed inside the furnace and then gradually heated to the temperatures of 850^{o}C, 900^{o}C and 950^{o}C respectively. They were soaked at the time intervals of 30, 45 and 60 minutes at each of the carburizing temperature. After which they were removed and quenched in water to hardened. Thereafter, tempered at the temperature of 200^{o}C for half an hour to relieve the residual stresses introduced into the carburized steel as a result of quenching.

For effective study of the internal structures of the carburized steel specimens, standard metallographic techniques were adopted. Thereafter, the specimens were placed on a metallurgical microscope which was adjusted to focus the specimens, and the microstructures were photographed, using a magnification of x400. The hardness values were taken at three different spots on each of the specimen and the average value were calculated. The energy absorbed in joules by the specimens on impact were also determined.

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Table 1: Chemical composition of the low carbon steel as-received

Elements	% Composition
C	0.182
Si	0.220
Mn	0.393
P	0.025
S	0.004
Cr	0.085
Ni	0.011
Mo	0.002
Al	0.031
Cu	0.053
Co	0.003
Ti	0.001
Nb	0.002
V	0.002
W	0.032
Pb	0.001
B	0.002
Sn	0.003
Zn	0.002
As	0.005
Bi	0.001
Ca	0.001
Ce	0.003
Zr	0.001
La	0.002
Fe	Balanced

Figure 1: Photograph of periwinkle snail shells.

RESULTS AND DISCUSSION

The results obtained from the experiment are presented in Table 2. Figure 2 to 5 show the variation of the mechanical properties (hardness and impact strength) with the process variables (carburizing temperature and soaking time). The micrographs of some of the carburized steel specimens are shown in Figures 6 to 11. Table 1 show the effect of carburizing temperature and soaking time on the mechanical properties of quench-tempered low carbon steel. It is evident in Table 1 that as the carburizing temperature and soaking time was increased from 850 to 950^{0}C at the time intervals of 30, 45 and 60minutes, there was a progressive increase in the surface hardness of carburized steel while the impact strength significantly decreases. The maximun surface hardness values of 53.7, 58.4 and 59.1 HRC were obtained at the carburizing temperature of 950^{0}C at 30, 45 and 60 minutes soaking time respectively. However, the uncarburized low carbon steel had the highest impact strength of 27J, while the minimun was obtained for the steel carburized at 950^{0}C for the soaking time of 60minutes. The variation in the surface hardness of the carburized steel specimens is expected since the enrichment of the surface layer of the steel with carbon increases exponentially with temperature and the case depth increases with time (Singh, 2011, Khanna, 2008 and Singh, 2007). Also, the higher the amount of carbon absorbed into the steel, the higher the hardness of the martensite formed. Therefore, the amount of carbon absorbed into the steel at different carburization temperature remarkebly affected the amount, proportion and morphology of the martensite formed during quenching. This in agreement with several authors (Nwoke, *et- al*. 2014 and Raghavan, 1989). The relatively lower impact energies exhibited by the carburized specimens is due to presence of the hard martensitic structure whose brittleness increases as the hardness of martensite increases.

Table 2: Mechanical properties of carburized low carbon steels

Carburizing Conditions		**Tempering Conditions**		**Hardness HRC**	**Impact energy** (Joules)
Heating Tempt (°c)	Soaking Time (min.)	Heating Tempt (°C)	Soaking Time (min.)		
Control	-	-	-	38.0	27
850	30	200	30	39.4	24
900	30	200	30	40.9	23
950	30	200	30	53.7	15
,					
850	45	200	30	41.4	22
900	45	200	30	43.7	20
950	45	200	30	58.4	13
850	60	200	30	46.6	18
900	60	200	30	47.0	17
950	60	200	30	59.1	9

Print ISSN: 2055-8112: Online ISSN: 2055-8120

Figure 2 show the variation of hardness with carburizing temperature. The graph clearly show that, carburizing temperature had a pronouced effect on the hardness of the carburized steel specimens. The observed increase in the hardness with increased in carburization temperature from 850 to 950^{0}C could be attributed to the fact that for the diffusion of carbon inside a steel to have certain thickness of the case with enriched carbon requires that carbon should be able to to form a solid solution with austenite iron. This can only be achieved when the steel is heated to the austenitic temperature. Therefore, the higher the temperature, the more the solid solubility of carbon in austenite (Singh, 2007) .The more, the surface of the steel is been enriched with carbon , the more the hardness acquired by the steel when it is rapidly cooled. This is in agreement with several authors (Jaykant, 2009, Yang *et al*., 1995 and Vernon, 1992).

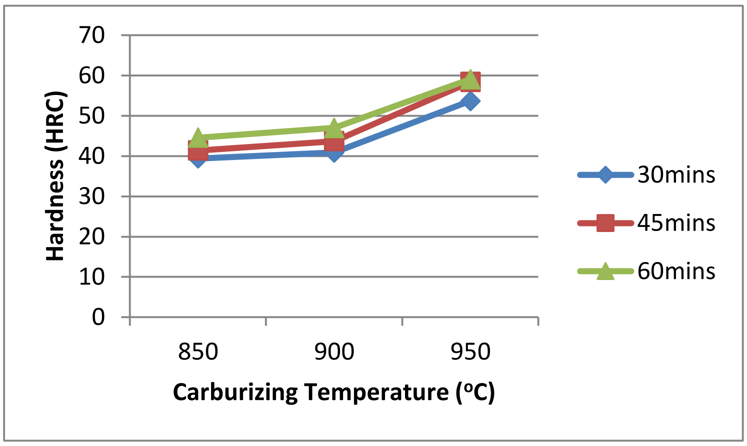

Figure 2: Variation of hardness with carburizing temperature

Figure 3 show the variation of hardness with soaking time. It is clearly evident from the graph that soaking time had a pronounced effect on the hardness of the carburized steel specimens. Report (Rajput, 2010) posited that at any given temperature, the longer the soaking time the heated steel is soaked in the carburizing compound, the more the diffusion of carbon inside the steel to form a high case depth. Hence, the variation of hardness of the carburized steel with increase in soaking time.

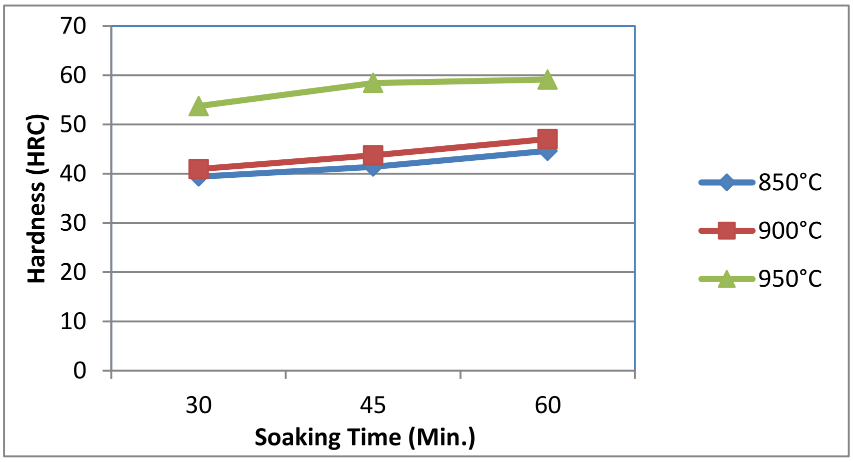

Figure 3: Variation of hardness with soaking time

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Figure 4 show the variation of impact strength with carburizing temperature. The graph show that the impact strength of the carburized steel specimens decreases as the carburization temperature was increased from 850 – 950^{0}C. This results is expected, since temperature is the controlling parameter for the diffusion of carbon. Also as the temperature increases, the amount of carbon absorbed by the steel also increases. Thus, the higher the temperature, the higher the carbon concentration at the steel surface and the higher the hardness of the martensite formed. Hence, the decrease in the impact strength which is caused by the increase in brittleness associated with the increase in the hardness of martensite.

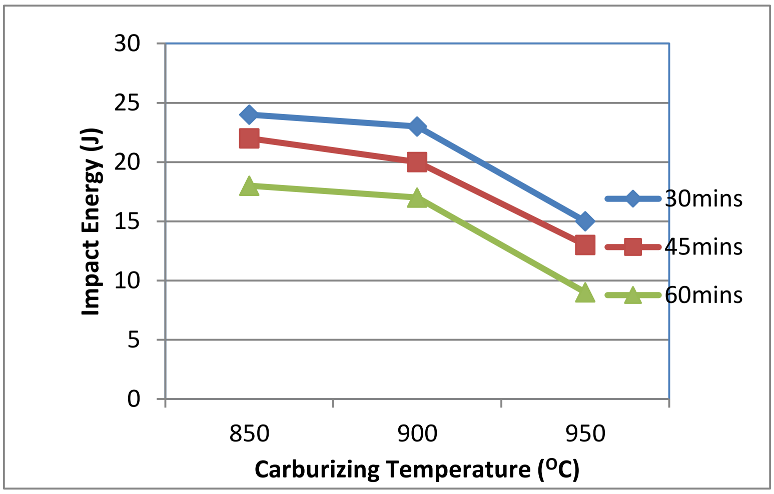

Figure 4: Variation of impact strength with carburizing temperature.

Figure 5 show the variation of impact strength with soaking time. It is clearly evident from the graph that the increased in the soaking time of the heated steel in the Carburizing medium decreases the impact strength of carburized steels. This result is expected since report (Rajput, 2010) revealed that at any given temperature, the absorption and diffusion of carbon inside steel increases with time. Hence, the presence of high carbon at the steel surface increases the hardness of martensite formed, thereby lowering the impact strength of the steel. This is in line with literature (Singh, 2007).

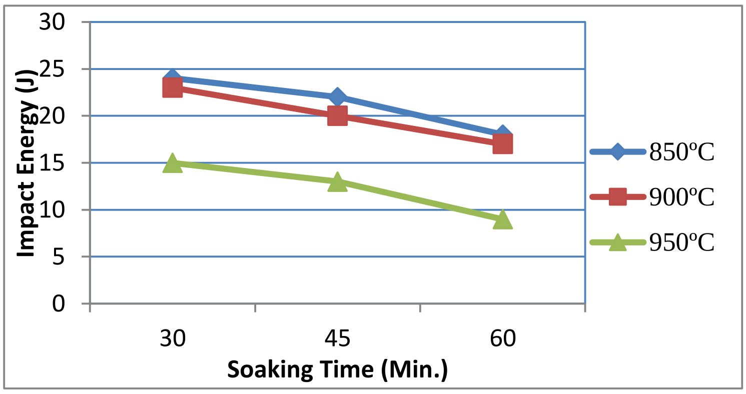

Figure 5: Variation of impact strength with soaking time

Print ISSN: 2055-8112: Online ISSN: 2055-8120

Figure 6 show the micrograph of the control (uncarburized) steel as-received. The microstructure revealed fine grained ferrite with some dispersed pearlite. The mechanical properties of the uncarburized steel specimen obtained (hardness and impact strength) are as a result of the characteristics features of the revealed microstuctural constituents.

Figure 7 show the micrograph of the steel specimen carburized at 850^0C for the soaking time of 60 minutes. The micrograph consists of tempered martensite in ferrite matrix. The presence of the tempered martensite in the matrix of ferrite accounts for the improved hardness and low impact strength when compared with micrograph of the uncarburized steel specimen.

Figures 8-11 show the micrographs of the steel specimens carburized at 900^0C for the soaking time of 60 minutes and 950^0 C at 30, 45 and 60 minutes soaking time respectively.The micrographs reveals islands of tempered plate martensite in ferrite matrix. The Figures evidently show that the regions of martensite islands increases with increase in the carburizing temperature. This implies that the amount and proportion of the martensitic phase increases as the carburizing temperature increases. Hence, the observed increase in the surface hardness and decrease in the impact strength of the carburized steel specimens. This is in agreement with Amalu *et al* (2012).

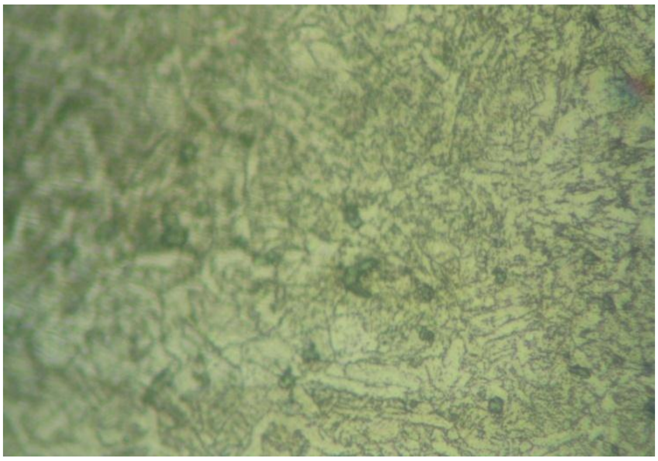

Figure 6: Microgaph of uncarburized (untreated) steel as- received. X400

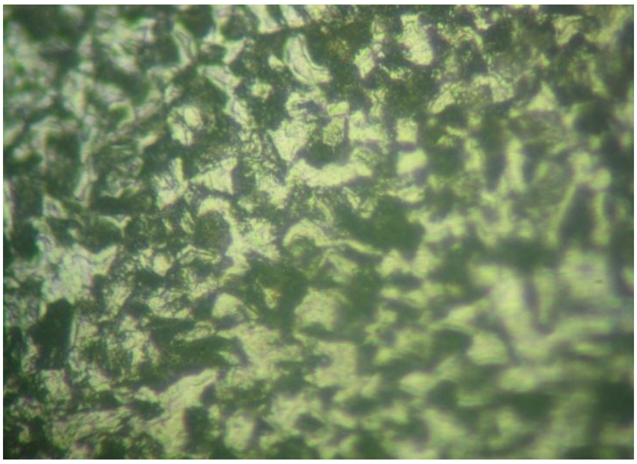

Figure 7: Micrograph of steel carburized at 850^0C and soaked for 60minutes. X400

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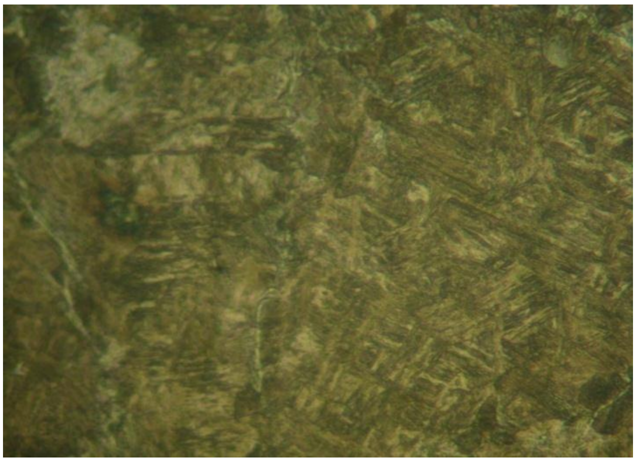

Figure 8: Micrograph of steel carburized at 900^{0}C and soaked for 60minutes X400

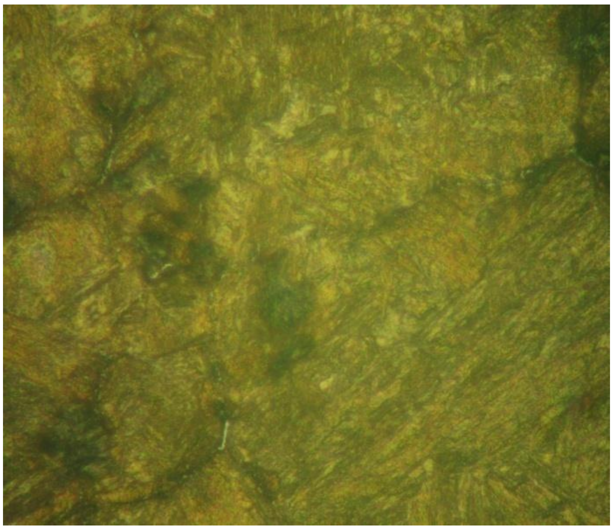

Figure 9: Micrograph of steel carburized at 950^{0}C and soaked for 30minutes. X400

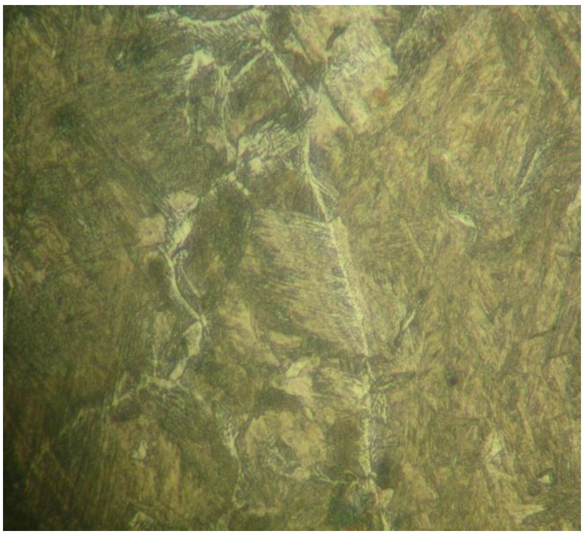

Figure 10: Micrograph of steel carburized at 950^{0}C and Soaked for 45minutes. X400

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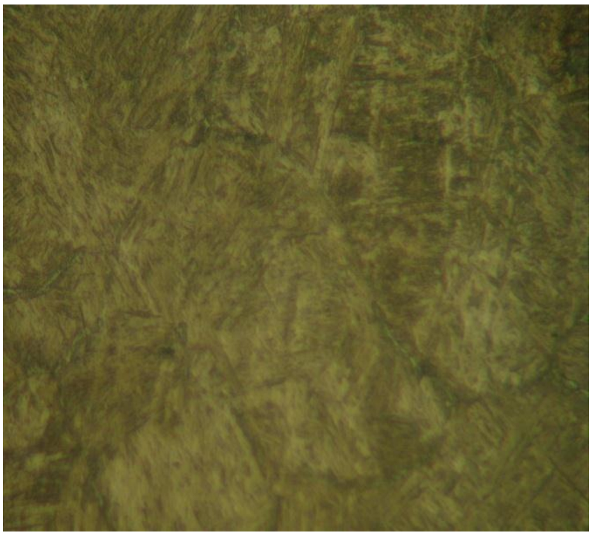

Figure 11: Micrograph of steel carburized at 950^{0}C and soaked for 60minutes. X400

CONCLUSION

The carburizing success as depicted by the improved hardness values of the carburized steel specimens which off course is a function of the process variables (carburizing temperatures and times) is an evidence of the carburizing potential of the periwinkle snail shells as an economically viable alternative local source of carburizing material for the surface hardness improvement of low carbon steel for use in application requiring higher hardness and wear resistance expected of some metallic components. The values of the impact strength of the carburized steel specimens showed that the carburizing temperature affected the degree of embrittleness cause by the surface treatment process.

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